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Estimating market power in the Internet backbone. Using the IP transit Band-X database

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Abstract

Recent studies have found the Internet backbone to be more competitive than was thought before. This paper explores a novel route to monitor market power using prices and quality data from the online trading site Band-X. First the hypothesis that Europe is a connectivity market on its own, is tested and then, by using a Panel data regression, the paper finds that these markets are not fully competitive since company specific reputation effects play a major role and price variations are only marginally affected by qualitative variables. Worryingly, companies with high prices are often able to supply an inferior quality transit.

JEL classification: C33; L13; L86; L96

Keywords: Internet; Market power; Backbone; Competition policy; Network industries

1. Introduction

1.1. The regulatory debate on international internet connectivity

International regulatory authorities are devoting increasing attention to the problem of international internet connectivity (IIC). The issue of whether, or not, to apply some form of

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ex-ante regulation has seen conflicting opinions across different countries, in particular between some Asian Pacific Countries and the US. The main disagreements concern the degree of competitiveness of the backbone market and the fairness of its connectivity tariffs. Australia was the first country to complain about IIC, in 1999 in APEC. This followed Telstra's initial complaint that it was paying too much money to North American internet backbone providers (IBPs) for international internet access and data transport. Other developing countries followed Australia's criticism arguing for the need to regulate backbone interconnection tariffs along the lines of international telephony settlements. These countries based their view predominantly on the evidence of asymmetric treatment of peering[1] and transit[2] policies implemented by the major backbones and on their adverse consequences for developing countries. China, which opened its telecom markets to competition and hosts some of the largest telecommunications operators in the world, is particularly critical[3] of existing arrangements. The United States, on the contrary, argues that, unless there is evidence of anti-competitive behavior or a realistic risk of fragmentation of the Internet, governments should avoid regulation and let companies decide on their bilateral interconnection regimes. The EU endorsed a series of studies[4] sustaining the argument that existing commercial agreements led to the establishment of effective competition in the market for Internet backbone connections. Hence, ex-ante regulation of connectivity prices should only be considered for those countries where a dominant incumbent operator has the control of the local access market; should this not be the case the monitoring of the backbone market should only be the subject of competition policy.[5] Indeed the main difference between Internet and conventional voice is that the settlement system for the latter evolved at a time when all international traffic was exchanged between national Public Telephone and Telegraphs (PTTs). By contrast, Internet traffic is exchanged between commercial entities not constrained within national borders. These entities have the previously unavailable option to route traffic in a global market for IIC and there are consequently fewer termination bottlenecks. The EU maintained, however, that the International Telecommunication Union (ITU) should promote information-sharing among regulators about international Internet connection charging arrangements and that governments and regulators should monitor the situation about the development and characteristics of the market for IIC.

The original recommendation dealing directly with the IIC issues dates back to ITU's World Telecommunication Standardization Assembly (Montreal, 6 October, 2000)[6] which approved recommendation D.50 stating that "…administrations involved in the provision of IIC negotiate

[1]"Peering has a number of distinctive characteristics. First, peering partners only exchange traffic that originates with the customer of one backbone and terminates with the customer of the other peered backbone. …As part of a peering arrangement, a backbone would not, however, act as an intermediary and accept the traffic of one peering partner and transit this traffic to another peering partner" (Kende, 2000).

[2]Transit arrangements occur when one backbone pays another backbone to deliver traffic between its customers and the customers of other backbones.

[3]See the two delayed contributions presented by the People's Republic of China as a formal white contribution (No. 16) to ITU Study Group 3 for its meeting on 10–14 June, 2002 with the title "Proposed changes to ITU-T Recommendation D.50" on new settlement principles and systems for the Internet.

[4]See Wik Consulting Report (2002).

[5]This regulatory approach was already agreed at the ITU World Telecommunications Policy Forum in 2001.

[6]For a fascinating account of the debate see Roseman (2003a,b).

and agree to bilateral commercial arrangements enabling direct international Internet connections that take into account the possible need for compensation between them for the value of elements such as traffic flow, number of routes, geographical coverage and cost of international transmission amongst others."[7] The recommendation, though not legally binding, has not been endorsed by Greece and the United States. The debate on the modification of this recommendation is still ongoing at the time of writing.[8] In particular a joint Internet traffic flow measurement project between the Chinese Academy of Telecommunication Research (CATR) and Electronic and Telecommunication Research Institute (ETRI) of Korea led the Chinese Ministry of Information Industry to contend that the principle of traffic flow measurement is feasible and should be used as a base to establish a new international Internet settlement system.[9] At the other end a contribution from industry emphasised that the concerns regarding the costs of access to the international Internet interconnect points were covered in the general principles as follows:

> Where one or more international links are required, arrangements for the international link capacities required and the apportionment of cost for the international link recognize that both parties bring value to the connectivity agreement. In determining the apportionment of cost, multiple methods of apportionment are acceptable, as long as mutually agreed to by both parties. Both parties have the right to make alternative arrangements, should the proposed arrangement not be acceptable. However where the international circuit links were provided under conditions of lack of effective competition, in the event competition abuses arise, these issues should be brought by relevant regulatory bodies to appropriate forums for discussion and resolution.[10]

The core of this debate on Internet access prices is inextricably linked to the distinction between peering and transit agreements, the main forms of Internet interconnection. This distinction, sometimes described as asymmetric network access discrimination, is predominantly based on measurements of network size and traffic[11].

Traffic and network asymmetries are in turn the results of the hierarchical structure and topology of the Internet. This has been changing rapidly: while the original Internet architecture was strongly US-centric, due to the historical legacy of the Internet's initial development, a contrasting centrifugal process is taking place. This has mainly been driven by: (a) the investment wave in backbone infrastructure of the second part of the 90s; (b) the cultural and linguistic differentiation of web contents; and (c) the application of new technologies and practices such as: caching, multi-homing and mirroring.[12]

[7]http://www.itu.int/newsarchive/press/documents/diii.htm.

[8](June 2004).

[9]See "Developing New International Internet Settlement Model" ITU, telecommunication standardization sector study period 2001–2004, regional tariff group for Asia and Oceania, delayed contribution 19 from China.

[10]See report of the joint rapporteurs' group meeting held in Brussels on 28–30 April 2004—final, study group 3—delayed contribution XX.

[11]See for example UUNet at http://www.worldcom.com/uunet/peering/.

[12]Caching: storing of already accessed data. Multi-homing: alternative routing can be arranged between origin and destination Mirroring: geographical or backbone multiplication of a web site's contents. See OECD (2002).

Another important change in the industry is provided by the rapid development of Internet exchange points (IXPs). Their role in reshaping the Internet topology is extremely relevant since they provide a cost effective high quality alternative to transit for the aggregation of regional traffic. Moreover new models of connections to the IXPs are emerging, so that, geographically, far-away networks can also become members of an Internet exchange by connecting through competitive carriers on a point-to-point basis. This capability that, first appeared in late 2003, will provide Internet Service Providers (ISPs) in countries that do not have good international connectivity available locally the opportunity to join Internet exchange communities much more cost-effectively.[13]

Internet traffic exchanges are losing their geographical link to specific physical places, and this process is eroding the original US location advantage. In fact a "de-agglomeration" process of Internet traffic is taking place, which has interesting consequences in terms of increased competitiveness of the backbone market and has implications viz-a-viz competition policy versus the ex-ante regulation debate. The new European Regulatory Framework[14] approved in February 2002 reflects this view and, while providing the means to enforce fair Internet access for local ISPs, does not recommend the introduction of ex-ante regulation for the sector.

The emphasis of the *European Directive* concerns general competition law and on the ability to detect, and punish, potential market dominance and its abuse. The focus is hence on the need to monitor, rather than to regulate, the market for international Internet connectivity and its evolution.

This monitoring task faced by competition authorities, is particularly daunting for the market for Internet connectivity. This is particularly so when it comes to defining the relevant market, both in terms of product space and of geographical extension, ascertaining the degree of market power of single competitors, monitoring the evolution of prices and their geographic differentials, evaluating the existence of entry barriers and detecting anti-competitive behavior or quality based non-price discrimination. The main problem is the elusive nature of the commodity traded, wholesale transmission of information packets along routes which are often recalculated at each step (hop), of the transmission process. While it is easy to calculate the traffic exchanges for traditional telephony, which travels along a dedicated circuit and to verify the associated economic transactions new and different tools are required to trace Internet traffic flows when, for example, even a single e-mail from Cambridge to San Diego, is decomposed in many sub-messages which may, or may not, reach the final destination traveling across different routes and networks while some of the network crossings are charged a fee and others take place for free.

The problems and/or desirability of having some degree of market power and hierarchy in the backbone was analyzed by Cave (1999) who raised the issue that the denial of free peering to small ISPs is, at the same time, solving a free riding attitude that could potentially lead to inefficiencies and congestion, while posing a threat of anti-competitive behavior. Possible ex-ante regulatory measures like obligation to peer or regulation of transit prices may induce distortions that are particularly worrying in the case of the Internet, which has shown spectacular growth and

[13]See for example the description of the *Linx from Anywhere* model: http://www.linx.net/joining/linx-anywhere/index.thtml.

[14]See the EU Directive on "Access to, and Interconnection of, electronic communication networks and associated facilities" (Official Journal, 2002).

diffusion in the absence of regulation. Other issues such as the effect of vertical and/or horizontal mergers are particularly relevant when it comes to monitoring the evolution of Internet topology. These have emerged during antitrust inquiries of the MCI Worldcom and MCI-Worldcom Sprint mergers conducted both by the Department of Justice in the US and by the European Commission.[15]

A subtler issue concerning regulators relates to the quality of the interconnection provided. Quality differentials are an indicator of market power asymmetries, since degraded quality of interconnection can be a powerful form of non-price discrimination in a concentrated industry. Crèmer, Rey, and Tirole (2000) modeled these aspects of quality competition for the backbone market and analyzed a ‘‘targeted degradation’’ strategy where the larger backbone lowers the quality of interconnection to its smaller rivals. Interconnection quality depends indeed on many aspects of the network, like its capacity, architecture and the number of peering, private and public, agreements. Hence a crucial aspect of the backbone market revolves around a mainly technical question, ‘‘How hierarchical is the Internet backbone?’’

An answer to this question requires the definition of the vertical boundaries of the relevant market, which in turn affects the determination of the geographical ones: how connected are the different national regional markets for Internet transit, and where should one draw a line when appraising their competitiveness?

The investment wave following the liberalization of the European Telecoms market at the end of the 90s has dramatically redesigned the Internet connectivity maps. Industry reviews by Oftel (2001) and OECD (2002), suggest that there has been a change in the formerly vertical US—centric backbone architecture. The rapidly changing geography of cyberspace requires therefore a continuous scrutiny since its forms, links and borders define the need for, or the irrelevance of, public intervention in this industry.

1.2. This paper

Estimates of market concentration in the Internet backbone can provide very different conclusions depending on the measurement approach used. For example[16] revenue based estimates present serious problems due to the mixing of revenue data from different Internet segments, and they are particularly misleading for vertically integrated backbones. Traffic based market share measurements are particularly difficult to obtain given the proprietary structure of the backbones. Routing techniques for the estimate of backbone market shares are based on an annual survey counting the upstream interconnections of ISPs carried by Boardwatch[17] but have been criticized for not considering the individual relevance of these connections. Finally a network architecture based approach[18] considers international Internet connectivity solely on deployed and operational bandwidth.

[15]For a discussion of these issues see, for example, Giovannetti (2004) and the original documents: Official Journal of the European Commission (2000) and US Department of Justice (2000). For an introduction on regulation and competition issues in telecommunications see Laffont and Tirole (2000).

[16]For a comparison of different approaches see Abramson (2000).

[17]Boardwatch ISP directory provides a count of the upstream interconnection for the providers, this has been used by the DoJ in its main antitrust inquiries.

[18]This data are collected by Telegeography, Inc.

This paper explores an *economics*, price-based, perspective to complement existing metrics techniques used to assess market power, and its potential abuse, in the Internet backbone. This approach is made possible by the appearance of online Internet transit (OIT) trading places in the market for Internet connectivity. OITs allow bandwidth trading through a centralized process with transparent prices while providing quality of service information. The immediate consequence of the appearance of these market operators is that while data on pricing and quality of internet protocol (IP) transit were often specified in bilateral contracts and kept confidential, now prices are becoming available and can be used for benchmarking the industry. For example the Band–X trading place provides daily prices for monthly Internet transit at different bandwidths, from its trading floors in London and New York.

As for the question of how representative the OIT markets are for the entire Internet transit market the answer has to be articulated at different levels. Concerning Band-X, the backbones offering Internet transit through this OIT are some of the world's relevant international and national carriers: Level 3, NTT Communications, Telefonica, Globix, Tiscali, Nildram, Sprint, Reach, MFN. Collectively these companies represent a relevant share of the transit market. From a theoretical point of view, the viability of two parallel markets, OITs and private undisclosed bilateral agreements, in which the same agents can buy the same product from the same suppliers, suggests that OITs represent at least an upper bound, an exit option available to all transit buyers located not too far away from the OIT access points. Therefore, it is acceptable to extrapolate from this sample OIT to be able to infer the working of the Internet transit market as a whole.

This work focuses on the following issues: it starts by comparing the connectivity prices in the IP transit markets of the Band-X London and New York on-line trading floors. This is relevant in defining the geographical scope of transit markets which is a preliminary step in antitrust investigations. It then focuses on the IP quality indexes to see whether the price convenience implies a lower connection quality.

The main empirical contribution is the result of a panel data regression which shows that the little price variance that there is, is mostly explained by the companies' dummies. This indicates that these specific markets are not very competitive, and that reputation effects play a major role since price variations are only marginally affected by qualitative dimensions. Interestingly, the sign of the coefficient is not necessarily the "right" one. This suggests again that the market is not entirely competitive since companies with high prices sometimes supply an inferior service.

2. The Internet supply side

The supply side of the Internet has players that can be divided into functional categories:[19] Internet service providers, providing retail access, Internet exchange points, forming the physical interfaces between networks and Internet backbone providers carrying data traffic, across long distance on fiber optic cables. At each node they provide routing of the information packages to direct each incoming message to the next step of its path. Backbones are usually classified as Tier

[19]It is however important to keep in mind that overlaps between functions are often observed, partially as a result of vertical integration, and M&A activity.

1, 2 and 3 depending on their relevance and connectivity strength. This hierarchical classification is however under scrutiny because of the rapid expansions of the connectivity maps of non-US backbones which are now often able to offer end-to-end connectivity, without necessarily depending on the original Tier 1 of US backbones.[20]

Each single network is connected along two dimensions with the rest of the net both by sharing the same transmission control protocol (TCP)/IP, the communication protocol providing a common language for computers to exchange information, and through the physical network interconnection points. Traffic growth and commercialization have initially led much of this interconnection from being carried at NAP's to migrate towards exchanges at bilateral interfaces. However, in more recent years new IXPs are emerging in Europe and they are playing an increasingly relevant role in efficient and cost effective intra-European traffic routing.[21]

2.1. The price of Internet connectivity

While the rapidly expanding number of IXPs, particularly in Europe, simplifies the information package routing, by reducing the number of links and the average distance travelled, the connectionless nature of the Internet still makes the price formation process far more complex than in traditional telephony.

Interconnection charges among backbone operators have been predominantly of the settlements-free type, for peering, while money is usually paid for transit arrangements. This implies that the upstream connectivity costs for an ISP can be divided into two main classes, the bandwidth costs required to connect to peering or exchange points and the transit charges when the data traffic leaves the original network outside a peering agreement. In summary an ISP in need of connectivity can buy it from an OIT and its cost is determined by the sum of the online selling price and the cost of connecting to the trading place.

2.2. Interconnection quality

Commoditization of Internet transit, facilitated by the emergence of a transparent trading place, usually provides higher incentives towards product differentiation. This shows, in particular, with the efforts to improve quality and reliability of the connectivity supplied. Quality depends on many aspects of a network like its capacity, architecture and the number of peering, private and public, agreements. There are, however, some simple ways of testing the quality of connection and build quality indexes. In particular Band-X provides a quality index of the IP connectivity based on the network statistics described below.

> "The monitoring metrics used are: -'Traceroute' which measures the number of hops (or routers) which traffic passes through to get to a destination and back. This figure should ideally be as small as possible.- 'Ping' is used to provide packet loss information, which indicates how much traffic is being lost, usually an indication of congestion or problems occurring on the

[20]For a detailed analysis of the development and construction of these end to end networks see OECD (2002).

[21]See for example the European Internet Exchange Association website: http://www.euro-ix.net. For an analysis of the role of IXPs on agglomeration in the Internet see: Giovannetti, Neuhoff, and Spagnolo (2004, 2005).

Table 1
Completed and planned non-US route miles

Network	Completed non-US route miles	Planned non-US route miles
360networks	31,000	42,700
Global crossing	NA	80,000
Level 3	3591	4750
Qwest	37,825	37,825
Williams Communications	NA	31,000
WorldCom	22,000	22,000

Source: Bank (2001).

network. This should be zero in a network performing properly. This metric also delivers the round trip time in milliseconds for the traffic to travel to and from a remote site. Again, the shorter the time, the better. -Throughput—the rate at which information travels across the IP network, is measured by examining the transfer rate for replies to HTTP requests for information on specific websites.'' [Source: www.Band-X.com.]

2.3. The European backbone market

In December 1999 the European Commission's eEurope[22] plan defined its three main objectives, of obtaining a cheaper, faster and secure Internet and identified the unbundled access to the local loop as a short term priority to bring about a substantial reduction in the costs of using the Internet. However high speed open access to the local loop is not sufficient to achieve, per se, the eEurope objectives. Indeed one of the main problems in securing a fast and cheap Internet access arises, not in the final connections between users and ISPs, but in the costs and quality of the connections between ISPs and the rest of the Internet. This issue has emerged in the drafting of the new EU Directive on access and interconnection. In 1998 the association of European ISP's, EuroISPA (1998), pointed out that it was, in fact, common for many European ISPs to lease bandwidth to the United States to route intra-European traffic, as this was often commercially convenient[23] though technically inefficient. In the late 90s, however, entrants in the backbone market have deployed large amounts of route miles of fiber network as shown in the Table 1 above:

Moreover, the amount of bandwidth which can be provided on a given strand of fiber has increased enormously because of the improved ways of exploiting fiber such as the dense wave division multiplexing (DWDM). An assessment of the impact of this investment wave on the competitiveness of the backbone market in the United Kingdom has been published by Oftel.[24] By

[22]For account on this see Giovannetti, Kagami and Tsuji (2003).

[23]In 1998, for example, the monthly cost for a 2 Mbps connection between London and Paris was of 38.000 $ while the same capacity connection between London and Virginia (the closest extra-European exchange point) was $30.000 even though Virginia is almost 25 times further away from London than Paris, EuroISPA(1998).

[24]See Oftel (2001).

Table 2
Connectivity markets for typical 10 Mbps contracts in London and New York

		London Price (in £)	Quality index	New York Price (in £)	Quality index
EU	Average	1331.3	118.8	1482.1	19.2
	Var	27,932.8	756.2	14,3476.1	938.4
	St. dev.	167.1	27.5	378.8	30.6
	Best	1080	144.1	799.0	24.0
US	Average	1331.3	52.7	1482.1	285.5
	Var	27,932.8	107.0	14,3476.1	25,959.9
	St. dev.	167.1	10.3	378.8	161.1
	Best	1080	61.9	799.0	524.3

Source: Calculations on data provided by Band-X.

using the test of the hypothetical monopolist[25] to design the vertical boundaries of the market, Oftel came to the conclusion that Internet connectivity constitutes a market on his own. The definition of the geographic extension of the market for Internet connectivity identified three possibilities for buying connectivity for a British ISP: (a) in the UK, (b) elsewhere in Europe, or (c) in the US. Oftel's inquiry found that the additional costs faced by a British ISP for buying connectivity outside the UK are high enough to make the UK Internet connectivity market competitive and therefore "self-contained". This finding conflicts with the earlier EuroISPA statements about the convenience of acquiring US-based connectivity, and shows the effects of the recent evolution of the European backbone industry often described as *fiber glut*. In particular Oftel found over 20 suppliers of Internet connectivity in the UK and failed to identify any operator as having a dominant position in terms of market volume. In its review,[26] Oftel reached the conclusions that the wholesale IP transit market in the UK is effectively competitive and wholesale prices are falling.

This paper's analysis of the price and quality data from on-line bandwidth trading floors confirms the conclusion reached by Oftel and the OECD (2002). For example Table 2, above, presents daily trading data for a typical 3 months contract for 10 Mbps of bandwidth in Band-X's London and New York trading floors, as recorded in the period 3 July to 5 November, 2002. Moreover the quality data are provided according to traffic destination: quality towards the EU, first row, and towards the US, second row.

It is worth noting that connectivity at 10 Mbps is cheaper in London than in New York on average. Yet the best price can be found in New York. The quality index of connectivity (as calculated by Band-X) is substantially better in London for connectivity with the EU. For

[25]From the Oftel document : "A product is considered to constitute a separate market if a hypothetical monopoly supplier could impose a small but significant, non-transitory price increase without losing sales to such a degree as to make this unprofitable. If such a price rise would be unprofitable, because consumers would switch to other products, or because suppliers of other products would begin to compete with the monopolist, then the market definition should be expanded to include the substitute products." (Oftel, 2001).

[26]Oftel's review focussed on the intermediate level of Internet connectivity.

connectivity with the US, New York maintains a considerable advantage with an average quality index that is more than four times that for London.

The importance of the actual physical location of the ISP's connection to a backbone is on the whole confirmed. When quality is considered London proves far better for European connectivity at 10 Mbps, while New York is the best market for US connectivity. On the whole these results would seem to indicate a marked change from the situation of the second half of the 1990s when a European ISP was often better off by buying bandwidth in the US even if its main interest was in connectivity with the EU. These results seem to confirm that the European market is currently characterized by an abundant supply of physical capacity.

ISPs with a definite interest in regional connectivity are better served by the bandwidth-trading floor closer to the prevalent destination of their communication needs.

Yet one would like to convey a word of caution on the robustness of these results. In particular the reader should be aware that on-line bandwidth trading is still in its infancy and therefore the prices and quality indexes here presented might be not fully representative of the entire transit market. Yet, they are valuable in two respects. First, they provide what could be defined as an informed guess on the geographical stratification of backbone market that confirms the current prevailing view. Secondly, they provide an example of the richness of information that can be gathered from on-line sources on the structure and functioning of the Internet backbone capacity market.

3. Panel data regressions

The data-set provided by Band-X contains prices by gross-connectivity supplier, location of the physical connection (London or New York), capacity band (10 Mb/s, 100 Mb, 1 Gb), and contract length (1 month, 3 months, etc.). The site provides also indexes of the qualitative performance of the various suppliers. These indexes are: Round Trip Time in microseconds, the Packet loss in percentage, Transfer rate (in kbytes/s); the number of hops necessary for a packet to reach a number of customary pre-defined destinations; and a summary Quality Index (used for example in Table 2 above). All qualitative indexes are specific to each company. On the other hand, for technical reasons they are invariant across bands. The quality indexes are provided as moving averages of the performance of a particular supplier over a fixed period (typically 6 months, 3 months, 1 month, 2 weeks), or as daily observations.

All these variables: prices by band, supplier, contract length, and location; moving averages of quality indexes by supplier and destination of traffic; and daily observations of quality indexes by supplier and destination of traffic, have been observed on a daily basis for the entire period from 3 July to 5 November, 2002. The rich nature of the information by supplier was ideal to perform a panel data analysis of these connectivity markets in New York and London. The next set of tables shows the regression results for London and New York for IP transit on 10 Mb band, three months commitment contracts, and 24 h quality indexes.

Consider a fixed effects panel data model, for each firm i in the market its price is specified as follows:

$$\mathbf{p}_i = \alpha_i \mathbf{i} + \mathbf{X}_i \boldsymbol{\beta} + \boldsymbol{\varepsilon}_i, \quad i = 1, \ldots, N,$$

Table 3
Final regression summary for the London market, 10 mbps

Model summary[a]									
R	R square	Adjusted R square	Std. error of the estimate	Change statistics					Durbin–Watson
				R square change	F change	df1	df2	Sig. F change	
.987[b]	.973	.973	1.951E−02	.973	2348.506	12	771	.000	.318

[a]Dependent variable: PRICE.
[b]Predictors: (Constant), L, H, J, K, I, F, E, D, C, B, A, RTTEU.

where $\mathbf{p}_i$ is a $T \times 1$ vector of daily prices for firm i, $\mathbf{i}_i$ is (1,1,...,1) is a $T \times 1$ vector, $\mathbf{X}_i$ is a $T \times K$ vector of daily observations on quality indicators, $\boldsymbol{\beta}$ is a $K \times 1$ vector of coefficients, $\boldsymbol{\varepsilon}_i$ is a $T \times 1$ vector of errors, and α_i are non stochastic time invariant unknown firm-specific coefficients.

Stacking over the N firms in each market gives

$$\begin{bmatrix} \mathbf{Y}_1 \\ \mathbf{Y}_2 \\ \vdots \\ \mathbf{Y}_N \end{bmatrix}_{(TN\times 1)} = \begin{bmatrix} i & 0 & \dots & 0 \\ 0 & i & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & i \end{bmatrix}_{(TN\times N)} \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \vdots \\ \alpha_N \end{bmatrix}_{(N\times 1)} + \begin{bmatrix} \mathbf{X}_1 \\ \mathbf{X}_2 \\ \vdots \\ \mathbf{X}_N \end{bmatrix}_{(TN\times K)} \boldsymbol{\beta}_{(K\times 1)}.$$

The model is then estimated using OLS on the deviations from the market mean and the estimation includes only companies that traded for the entire period. Given the absence of a priori choices for the quality indicators, an exclusion methodology, aimed at minimizing collinearity and maximizing the model fit, has been used. The final regressions are presented below.

3.1. London

The panel data model above was deployed to regress the London price for transit contracts for 10 mbps[27], with one month commitment, against a set of quality indicators and company dummy variables. In particular, as the quality indicators are likely to have a delayed effect on demand, and thus prices, in the regression this effect was modeled by considering their weekly moving averages.[28] The final regression for the London market is summarized in Table 3.

The most notable features of this regression output are its close fit (an adjusted R square of 97%), and the fact that apart from round trip time to European destinations in ms (RTTEU) the only other statistically significant variables are the company dummies (A, B, C, D, E, F, H, I, J, K, and L). The coefficients are summarized in Table 4.

[27]The analysis of the London price for transit contracts for 155 mbps, provided very similar results.
[28]The Authors are grateful to an anonymous referee for this suggestion.

Table 4
Coefficients values and statistics for the London market, 10 mbps

Coefficients[a] Model		Unstandardized coefficients		Stand. coeff.	*t*		95% Confidence interval for B		Correlations			Collinearity statistics	
		B	Std. error	Beta		Sig.	Lower bound	Upper bound	Zero-order	Partial	Part	Tol.	VIF
1	(Cons)	.165	.003		61.911	.000	.160	.170					
	RTTEU	5.671E−02	.010	.093	5.703	.000	.037	.076	−.356	.201	.034	.131	7.635
	A	−.342	.003	−.812	−98.645	.000	−.349	−.335	−.460	−.963	−.580	.510	1.962
	B	−.265	.004	−.630	−67.170	.000	−.273	−.257	−.243	−.924	−.395	.393	2.543
	C	−.244	.003	−.580	−72.808	.000	−.251	−.238	−.223	−.934	−.428	.545	1.836
	D	−.283	.007	−.672	−38.377	.000	−.298	−.269	−.223	−.810	−.226	.113	8.880
	E	−.253	.004	−.601	−70.514	.000	−.260	−.246	−.223	−.930	−.414	.476	2.101
	F	−.244	.003	−.578	−69.843	.000	−.250	−.237	−.203	−.929	−.410	.504	1.986
	H	−.141	.004	−.271	−35.031	.000	−.149	−.133	.054	−.784	−.206	.578	1.731
	I	−.101	.004	−.239	−28.185	.000	−.108	−.094	.172	−.712	−.166	.481	2.079
	J	−9.904E−02	.004	−.224	−27.850	.000	−.106	−.092	.162	−.708	−.164	.535	1.870
	K	5.901E−02	.003	.140	17.635	.000	.052	.066	.568	.536	.104	.547	1.827
	L	−7.302E−02	.003	−.173	−21.770	.000	−.080	−.066	.222	−.617	−.128	.545	1.836

[a]Dependent variable: PRICE.

It is noticeable that the coefficient of RTTEU does not come with the expected negative sign indicating an inverse relation between the time needed for the packet to travel from a computer to its EU destination and back, and the price offered by the backbone.

3.2. New York

For New York the final regression (transit contracts for 10 mbps) shows a similarly high fit (adjusted R square $= 99\%$). Here, as in the previous model, only one quality variable appears to be statistically significant: the number of hops to European destinations (HEU). Along with it there is the usual host of statistically significant company dummies (P, N, and O) (Tables 5 and 6).

These results are not surprising, given the low variance of prices and given that most of it is between companies and it is mostly explained by the companies' dummies as shown by their high coefficients the fact that these coefficients are statistically highly significant. This indicates that the markets are not fully competitive, and that reputational effects play a major role. The existence of these effects in a supposedly anonymous market is probably the effect of disclosure after a number of interactions. The anonymity of the market is a feature that clearly decreases with usage.

Alternatively one may see these price differences as a signaling device that backbone providers use to identify themselves to the ISPs. There is, indeed, an important information asymmetry since only the seller knows its own true quality, while the OIT produces independent technical quality assessments for the benefits of the ISP, the final buyers of transit. Higher prices can then be used to signal higher quality, along dimensions not captured by the technical parameters checked by Band-X. Should this be the case asymmetric pricing could help reduce the negative impact of asymmetric information and allow ISPs to distribute their demand across backbones more efficiently and accordingly to their own reputation and-or technical quality preferences.

Price variations are only marginally affected by qualitative dimensions (low coefficients and, on the whole, less statistically significant). This is confirmed by the fact that the adjusted R-square remains high when entirely omitting these variables. The relative unimportance of qualitative indicators either indicates that these markets are of a non-competitive nature, or suggests the presence of substantial information asymmetries leading to price discrimination. Moreover, for technical reasons the quality indexes tend to move in synchrony, and therefore are responsible for most of the collinearity present in the initial regressions. The fact that only a few of them are

Table 5
Final regression summary for the New York market, 10 mbps

Model summary[a]									
R	R square	Adjusted R square	Std. error of the estimate	Change statistics					Durbin–Watson
				R square change	F change	df1	df2	Sig. F change	
1.000[b]	.999	.999	8.492E−03	.999	106109	4	375	.000	.155

[a]Dependent variable: PRICE.
[b]Predictors: (constant), P, HEU, O, N.

Table 6
Coefficients values and statistics for the New York market, 10 mbps

Coefficients[a] Model		Unstandardized coefficients		Stand. coeff.	*t*	Sig.	95% Confidence interval for B		Correlations			Collinearity statistics	
		B	Std. error	Beta			Lower bound	Upper bound	Zero-order	Partial	Part	Tol.	VIF
1	(Cons)	.364	.001		242.869	.000	.361	.367					
	HEU	−.706	.046	−.049	−15.301	.000	−.797	−.615	.810	−.620	−.023	.234	4.271
	N	−.821	.002	−1.252	−337.685	.000	−.826	−.816	−.896	−.998	−.518	.171	5.842
	O	−.360	.002	−.549	−181.995	.000	−.364	−.356	.025	−.994	−.279	.259	3.864
	P	−.281	.001	−.429	−190.566	.000	−.284	−.279	.162	−.995	−.292	.464	2.155

[a]Dependent variable: PRICE.

statistically significant in the final regressions shows that most of the information that each quality index conveys is largely redundant. Finally the sign of the coefficient is not necessarily the 'right' one. This suggests that the market is even less perfect than the high significance of the dummies might suggest, as companies with high prices are often able to supply an inferior service.

4. Conclusions

The Internet is a typical network industry, thus liberalization policies targeting the downstream markets are not effective when a serious attempt to oversee the access policies in the upstream markets is not undertaken. Within the ITU, the debate about the opportunity to regulate Internet international interconnection fees continued during 2004. Unfortunately, authorities are experiencing many difficulties when attempting to observe upstream relationships, as most bilateral interconnection agreements are confidential. Hence, greater transparency in the access policies, involving transit prices and peering agreements, is needed by the national and international regulatory authorities. Without the right information, in fact, it is not possible to undertake a proper market analysis, which is very important especially when there are firms that may enjoy elements of market power. When the industry consists of firms headquartered in different countries the introduction of an ex-ante regulation turns out to be quite difficult, hence, a crucial role is played by the possibility to monitor, and in the event, punish anticompetitive practices.

Different analyses of the Internet backbone market provide conflicting answers about its competitiveness and concentration. This variability is mainly due to the paucity of existing data as opposed to those required to design the vertical and horizontal borders of the relevant market. This paper used online transit prices to monitor indirectly the evolution of the Internet transit market, by-passing, in this way, the difficulties of mapping the borders and hierarchies shaping the Internet backbone structure. Many of the relevant questions have been addressed by using the available information on online IP transit prices and quality. This data indicates a changing structure of the Internet connectivity map, showing the emergence of a less hierarchical and multi-headed backbone structure with separate US and European transit markets. However this process seems to have left elements of market power, which may be specific to the role reputation factors still play in the infancy stage of online trading markets.

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